PXIE MEBT:
- accomplishments of FY12
- plans for FY2013
- possible “Phase I”

A. Shemyakin

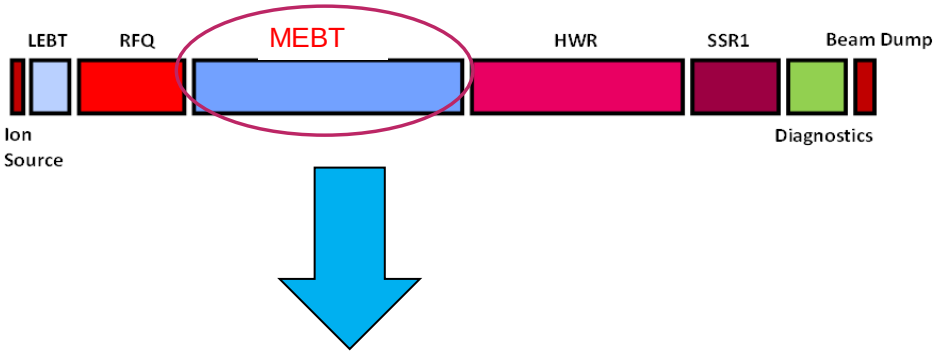
with help of many people mentioned in slides

October 2, 2012

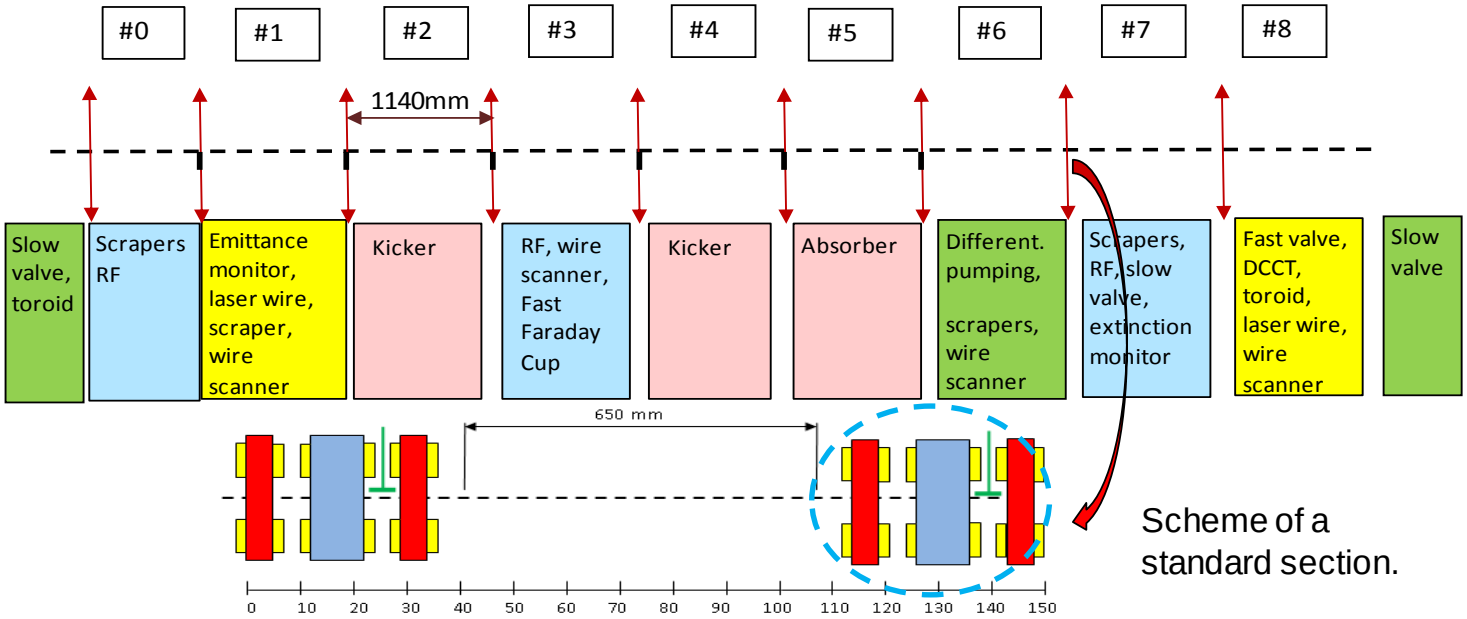
Project X meeting

MEBT scheme

- No changes in 2012



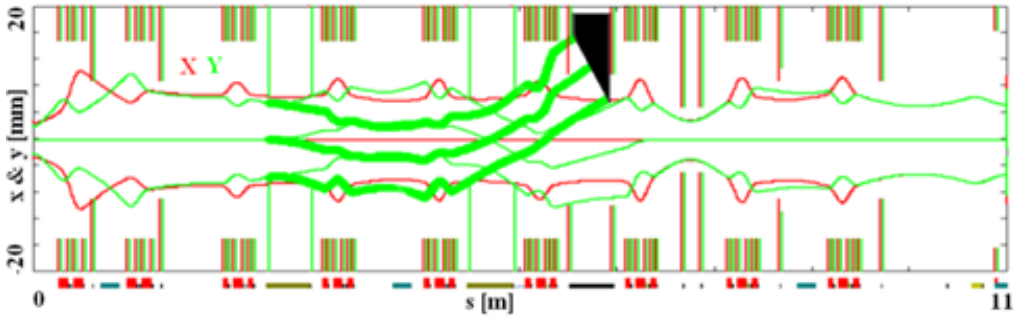
- MEBT consists of 9 sections with the total length of ~10m.
  - 8 sections have the identical length (1140 mm between centers of triplets)
  - The section #0 is shorter and is bounded by two doublets
  - ~ 90 deg phase advance between sections
  - Two kickers working in sync



Scheme of a standard section.

What was done in FY12

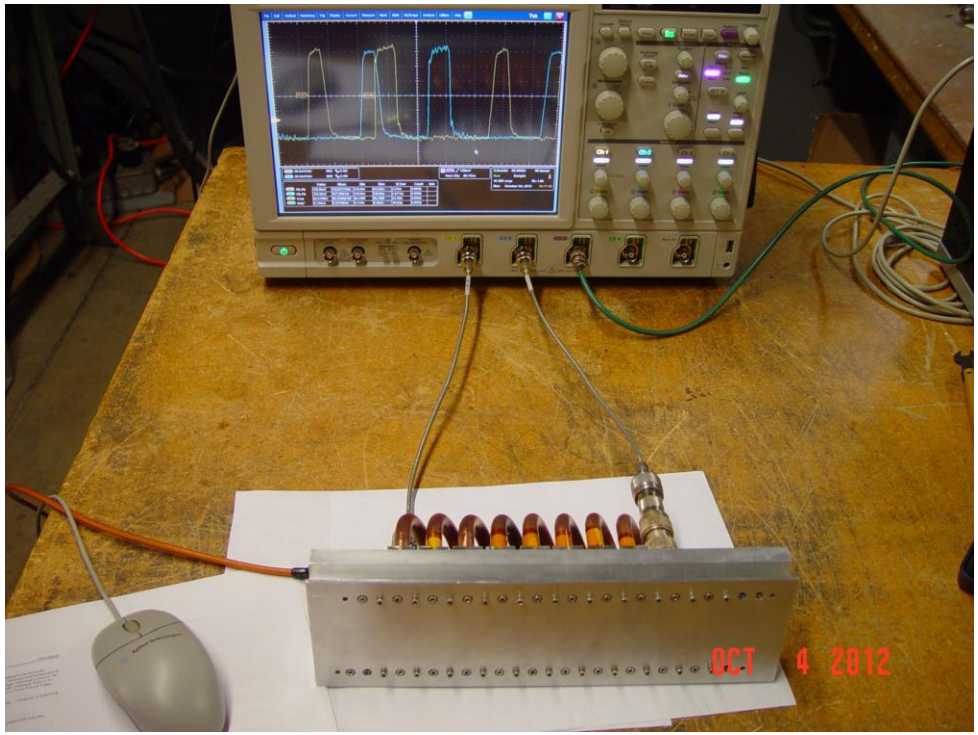
- Specifications were finalized
- The scheme was chosen
  - Optical design, approximate list and positions of elements, length
  - Draft FRS for main elements
- Part of PXIE cost estimate and schedule
  - Many people reporting to E. Peoples-Evans and B. DeGraff
- Major efforts were put toward
  - 50-Ohm kicker
  - 200-Ohm kicker
  - Bunching cavity
  - Quadrupoles
  - Absorber
    - Test bench



Scheme of MEBT optics [V.Lebedev] and the beam envelope. The thin lines are the central trajectory and 3σ envelope (e_{rms_n}=0.25 mm mrad) of the passing beam, and the thick lines are the Y envelope of the chopped-out beam. Red- quadrupoles, blue- bunching cavities.

50-Ohm kicker structure (1)

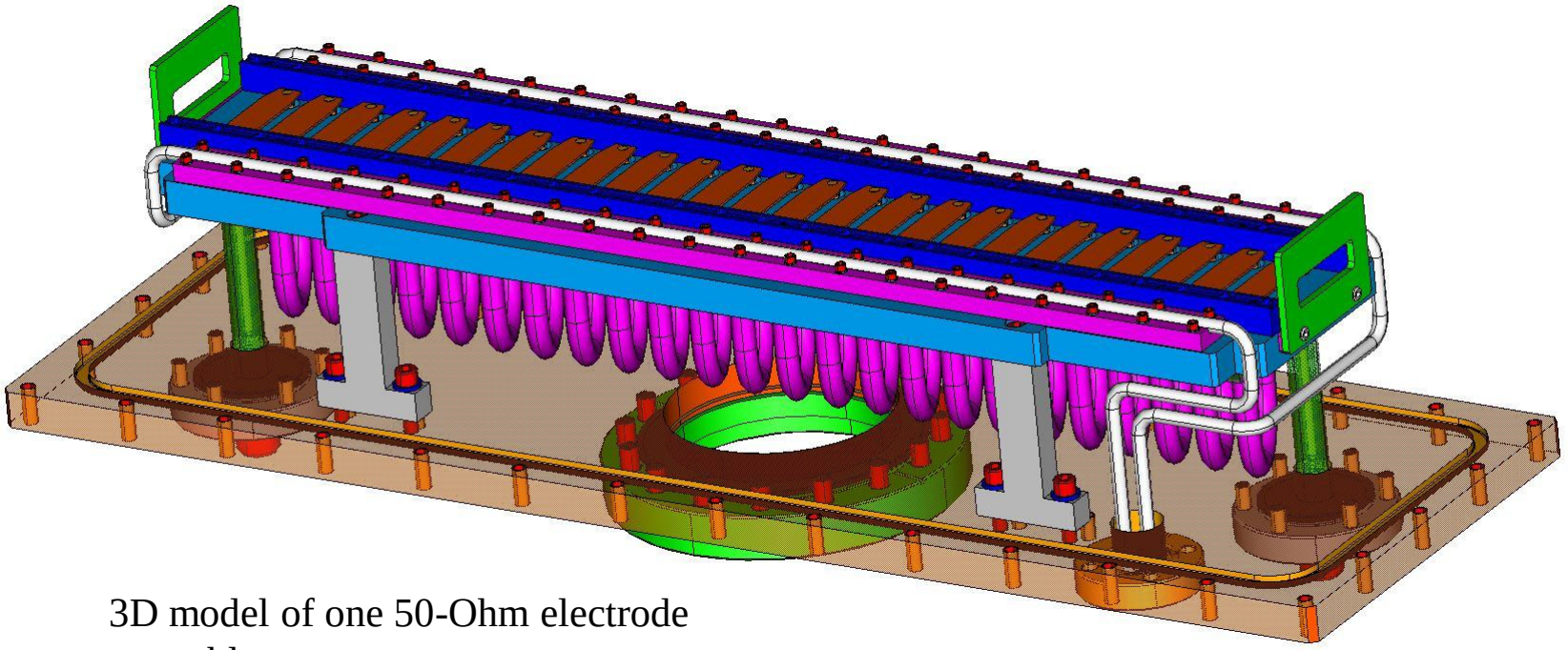
- RF design (D. Sun, V. Lebedev)
- RF measurements of a short model and components (D. Sun)
  - Successful. Scheme with cables is chosen
- A mockup with 8 plates and cables in their final RF configuration was manufactured, assembled, and successfully tested (D. Sun)



Measurement of a 8-unit mockup. Scope traces: yellow- input, cyan - output after the 8 delay units. The input trace consists of two consecutive pulses with different rise time. One is 1 ns rise time and the other is "0" ns rise time.

50-Ohm kicker structure (2)

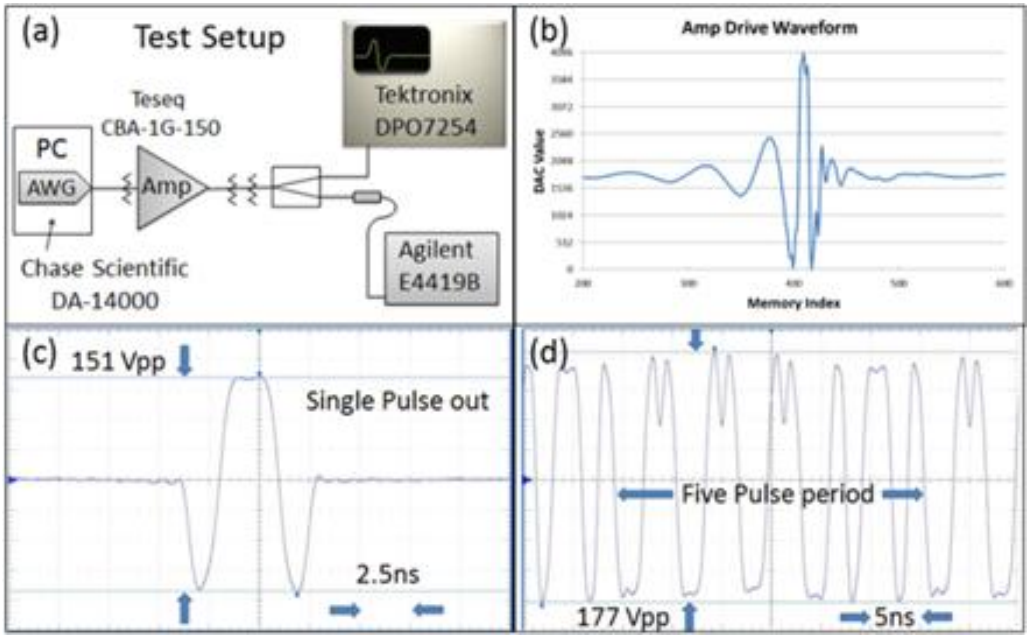
- Mechanical design (A. Chen, D. Sun, P. Jones)
  - The design is at the last stage of a complete 3D model
    - Review on November 1, 2012



3D model of one 50-Ohm electrode assembly

50-Ohm kicker driver

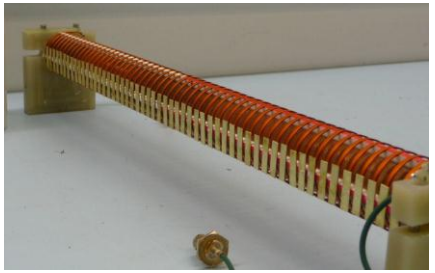
- Kicker driver
  - Choice of waveform and scheme (V. Lebedev)
  - Scheme was tested with 150W amplifier (R. Pasquinelli, D. Peterson, V.Lebedev)
    - Linear amplifier + pre-distortion
    - Successful
    - 1 kW amplifier can be ordered when needed and budget allows



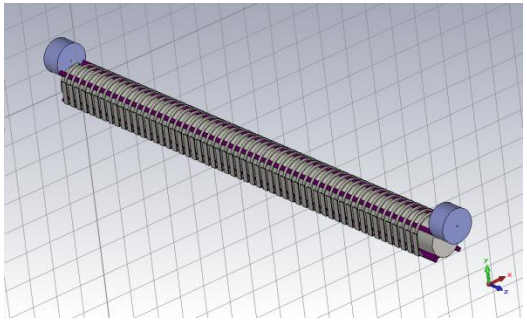
Test of the CBA 1G-150 amplifier with pre-distortion. (a) scheme of the test; (b) pre-distorted input signal and (c) corresponding output signal for a single pulse; (d) output for a CW pattern, corresponding to removal of four consecutive bunches followed by a one-bunch passage.

200-Ohm kicker

- Kicker
  - A 50-cm model measured (G. Saewert)
    - Properties are close to the requirements
    - The phase velocity and impedance need to be adjusted
  - Preliminary conceptual design of the kicker done (A. Chen, G. Saewert, P. Jones)
  - Preliminary solutions has been found for 200 Ohm feedthroughs, load, and transmission line (G. Saewert)
  - Simulations of the kicker structure (M. Hassan, T. Khabibouline; initial efforts – M. Wendt)
    - After several iterations, a good agreement with measurements
    - A geometry with correct phase velocity and impedance has been simulated
    - Present simulations are concentrated on finding a good solution for impedance near the ends
    - Results are to be reported soon at PX meeting



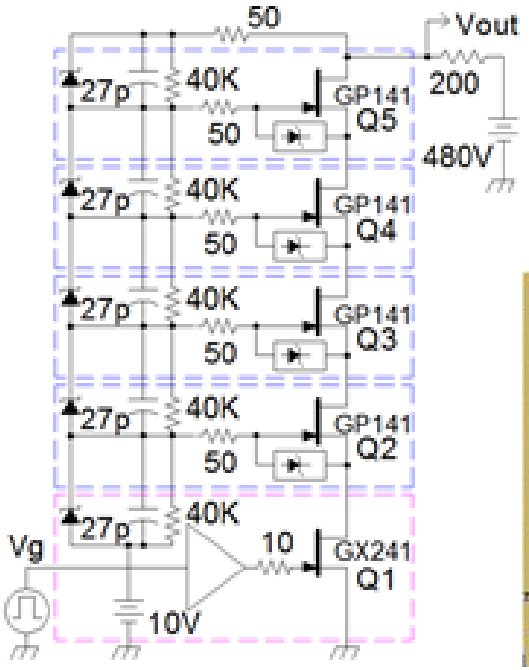
Electromagnetic model of the helix

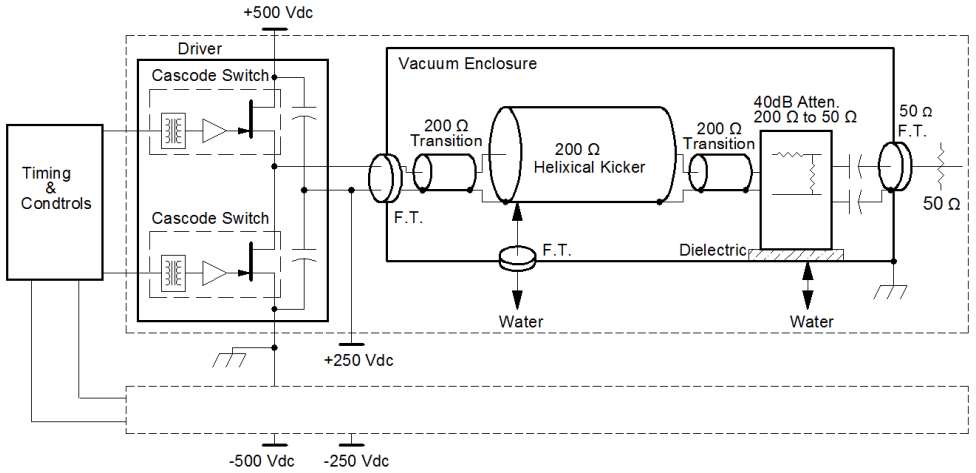


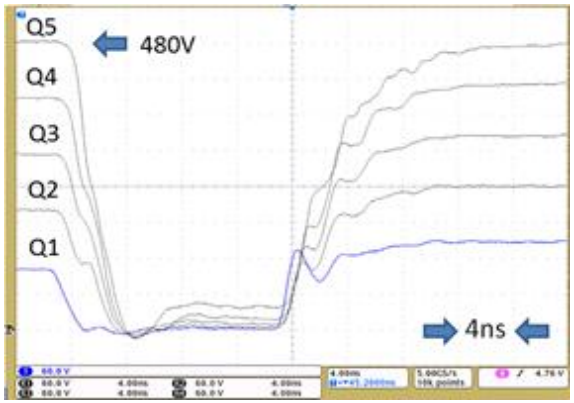
CST model for simulating the helix

200-Ohm kicker driver

- GaN multi-FET cascode scheme (G. Saewert)
  - based on five 200 V rated FETs
  - A prototype of one switch has been successfully tested
    - 480 V, 3 ns rise time



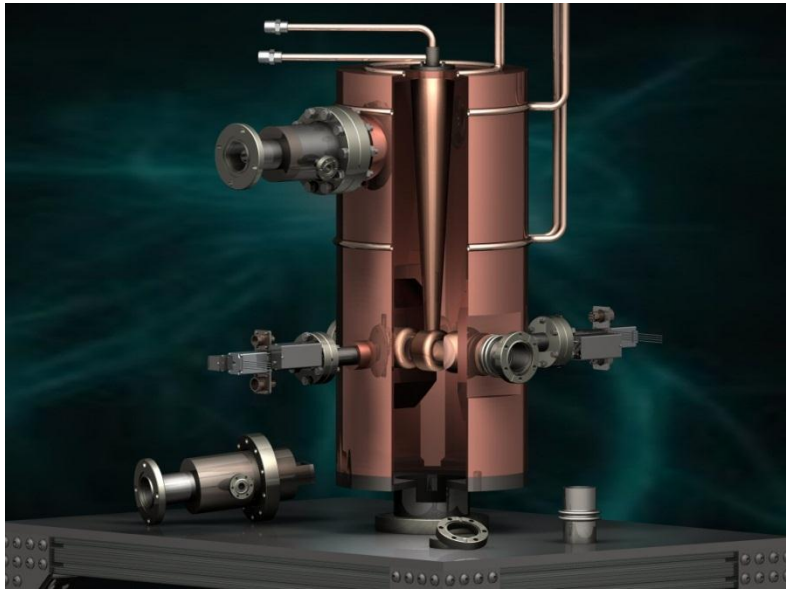


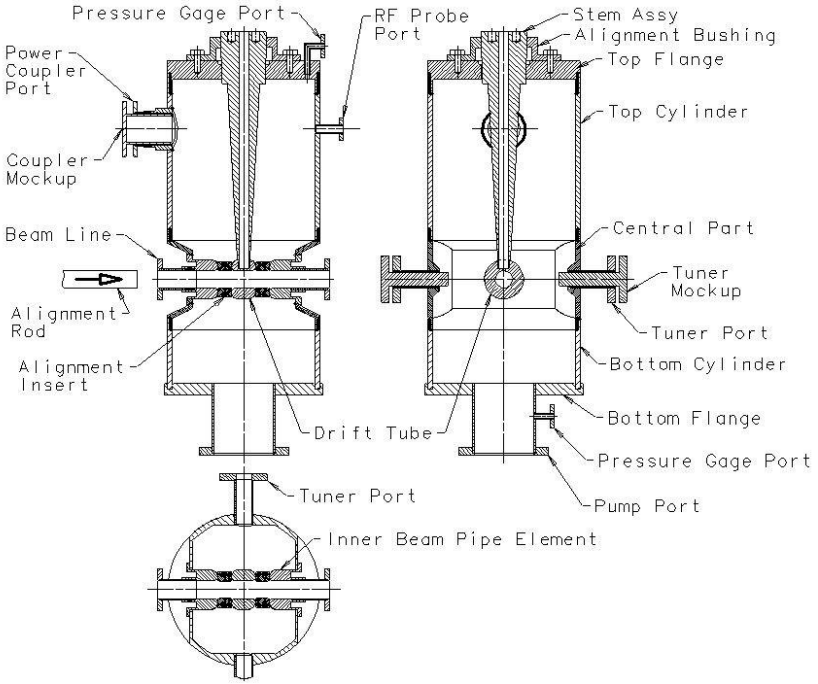


Simplified schematic of a multi-FET cascode switch and scope traces of the five FET drain voltages.

Buncher cavity

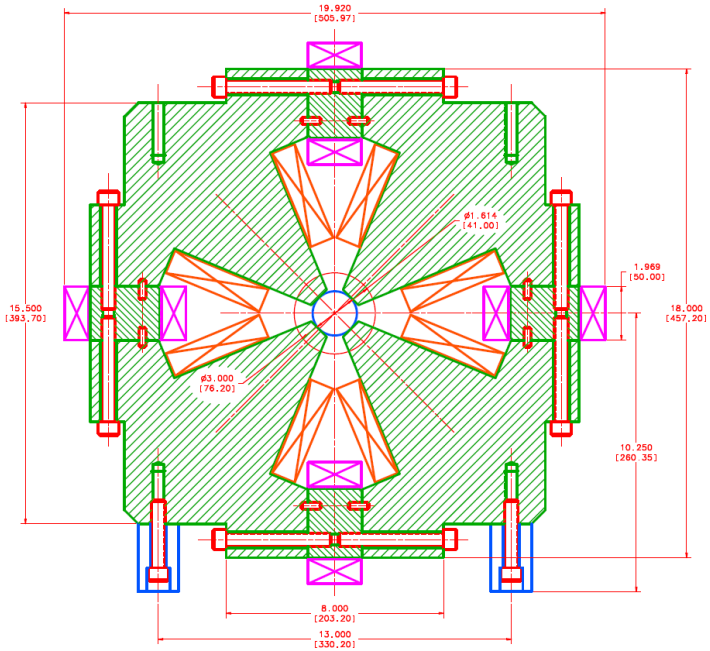
- Conceptual design is done (in TD)
  - Gennady Romanov (system configuration), Ivan Gonin (RF modeling) Timergali Khabiboulline (group leader), Meiyu Chen (mechanical analysis), Jodi Coghill (mechanical designer), Iouri Terechkine (integration, fabrication)
  - The technical design is being finalized
  - Discussion with a perspective vendor in parallel





Quadrupoles

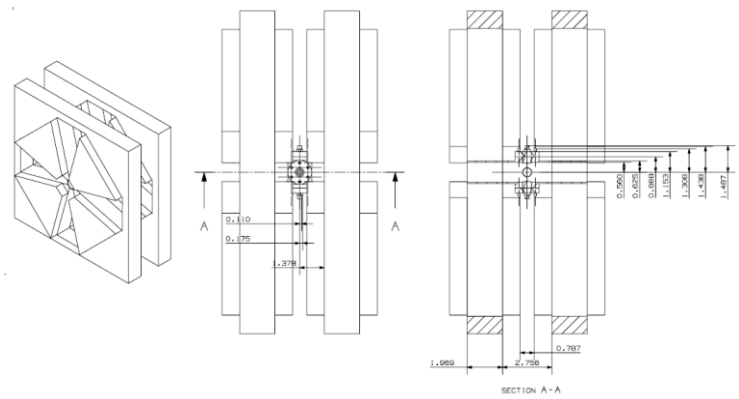
- At the stage of a magnetic design
  - Vl. Kashikin
  - The design was delayed by our request to TD to participate in LEBT solenoids
- The first version included dipole correctors
  - Low quality of the dipole field
  - Presently, a scheme with a separate dipole corrector assembly right downstream of a triplet is being considered



First draft of the quadrupole (A. Makarov, Vl. Kashikhin.

Other

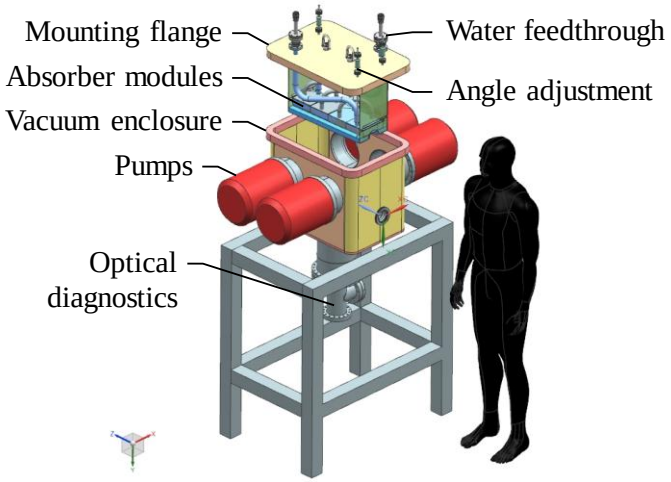
- Diagnostics (V. Scarpine)
  - Discussions
  - Sketch of a BPM (M. Alvarez)
    - To check compatibility with the quad design
- Controls (J. Patrick, M. Kucera)
  - Concept
- Power supplies, facilities etc.
  - Very beginning



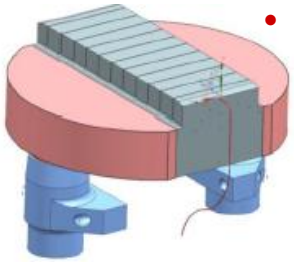
A button-type BPM sketched inside the draft version of the quadropole doublet (M. Alvarez).

MEBT absorber

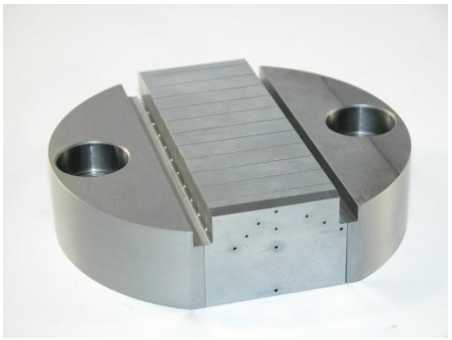
- Plan for FY12 was
  - A preliminary conceptual design of the full-scale absorber - done (C. Baffes)
    - Thermal and stress simulations, choice of material (TZM) (C. Baffes)
    - Estimations of radiation, secondary particles, and sputtering (Yu. Eidelman, I. Rakhno)
  - Technical design of a ¼- size prototype – done (C. Baffes)
  - Prototype manufacturing – in progress
    - TZM parts are ready
    - Need to be brazed and assembled
  - Design, assembling, and commissioning of a test bench for testing the prototype with an electron beam in progress (next slide)



Conceptual design of the absorber (C. Baffes)



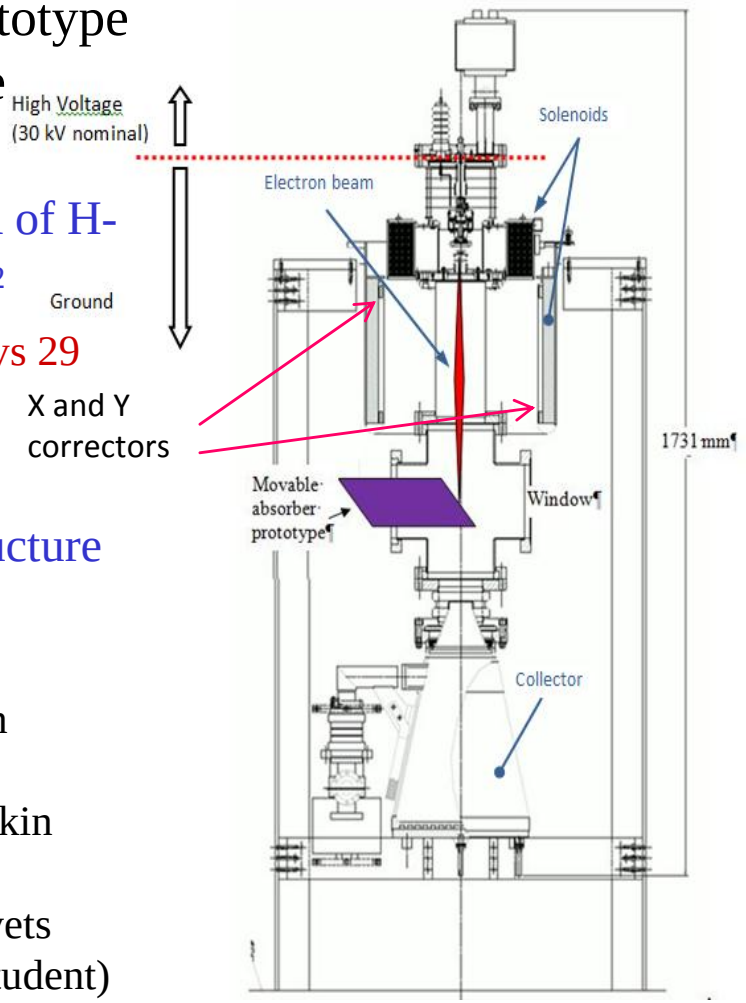
Design of the absorber prototype



TZM parts manufactured for the absorber prototype

Absorber prototype test bench

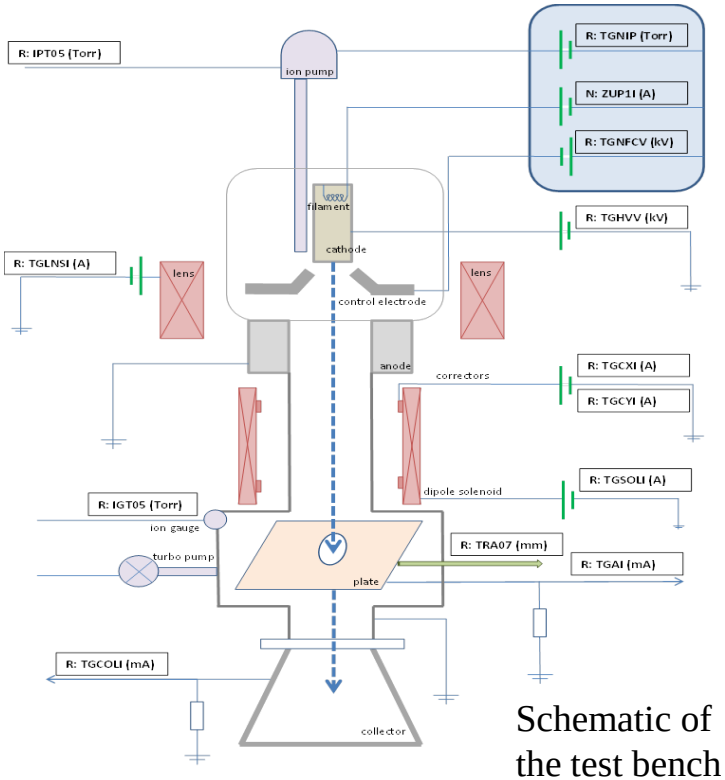
- Goal: to test thermal properties of a prototype with an electron beam at similar surface power density
  - 28 keV, 0.19A of e- vs 2.1 MeV, 10mA of H-
  - But the same power density~25 W/mm^2
    - Because of a larger grazing angle, 120 vs 29 mrad
- Parts mainly from the Electron Cooler
  - Assembled in MI-31 to use the infrastructure



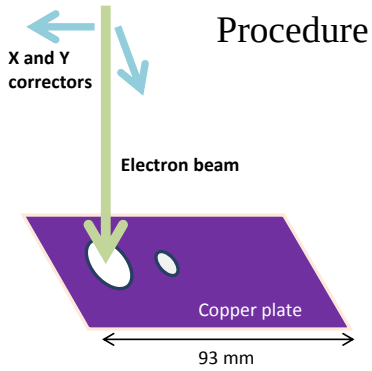
K. Carlson
B. Hanna
W. Johnson
L. Prost
A. Shemyakin
J. Walton
A. Mitskovets
(summer student)
with help from the Water group and Mechanical Support, and Safety

Absorber prototype test bench (cont.)

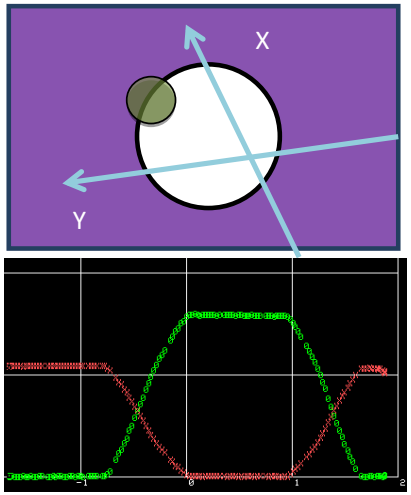
- First stage: beam size measurements -done
  - Scans over round holes in a movable, electrically isolated plate
    - A. Mitskovets (PARTI student): commissioning, calibration
    - Long-pulse mode
    - Found solenoid settings to provide the power density close the requirement



Schematic of the test bench



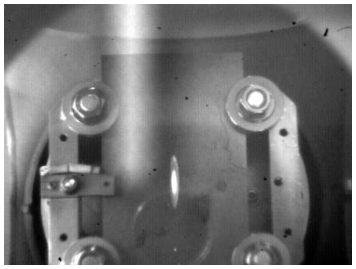
Procedure of corrector calibration

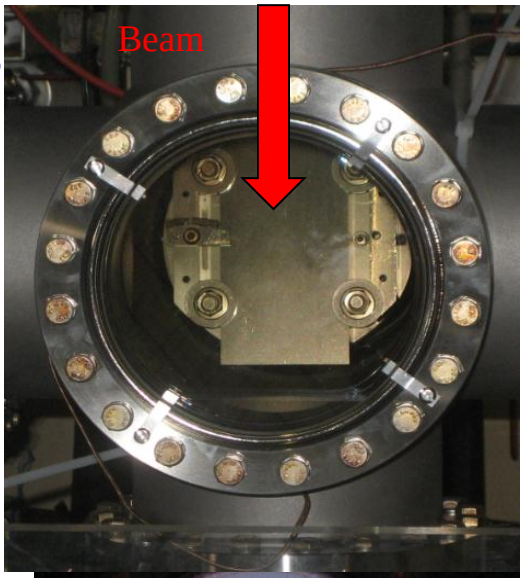


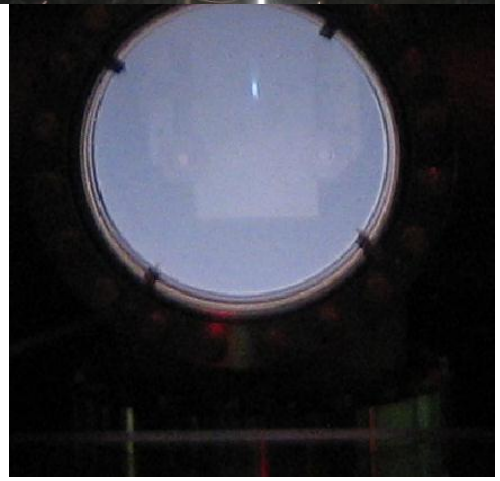
Example of a beam scan over a hole

Absorber prototype test bench (cont.)

- Second stage: pre-prototype – in progress
  - A standard TZM brick with simple water cooling (J. Walton)
    - Can be used as a kW-range beam stop for PXIE commissioning
  - Issues
    - Very large outgassing limits the speed of increasing the beam current. The outgassing coefficient has already decreased by > 20 times.
      - Developed a conditioning program (L. Carmichael, B.Hanna)
      - Preparing procedures for long runs (B.Hanna, M.Murphy)
    - Radiation from the ceramic gap (resolved- B.Hanna)
    - Heating of the vacuum chamber by secondary particles
  - OTR light from the absorber surface
    - Using it for beam characterization (R.Thurman-Keup, B.Hanna)
  - We plan to prepare a more detailed report soon







Resources available for FY13 and goals

- 5.5 FTE, 230 k$
- Goals
  - Go ahead with prototypes of
    - Kicker (both versions)
    - Absorber
    - Bunching cavity
    - Quadrupoles
    - Instrumentation (BPMs)
  - Conceptual designs
    - Full-scale absorber
    - Vacuum system
    - Scrapers
    - Emittance monitor
  - Write specifications
    - All diagnostics
    - Power supplies
    - Infrastructure

Plans for FY13 – Kicker

- 50- Ohm version
  - Production drawings- Dec 2012
    - A review on Nov 1, 2012
  - Full-size prototype manufactured – Mar 2013
  - Tests begin – May 2013
    - Low – power RF measurements
    - Vacuum tests
    - High – power measurements (with a similar frequency, full-power amplifier)
  - If the tests are successful, final drawings may be ready by the end of FY13
- 200-Ohm version
  - EM design- Dec 2012
  - Final conceptual design- Feb 2013
  - Production drawings- May 2013
  - Full-size prototype manufactured - Sep 2013
    - To begin tests in FY14
  - Prototype of the driver with parameters close to final is tested Sep 2013

Plans for FY13 – absorber

- Nov 2012 – the test bench is fully commissioned
  - All controls, programs, and procedures are in place
    - Image monitoring
- Nov 2012 – prototype is assembled
- Dec 2012 – Feb 2012 – prototype testing
  - If it fails, prepare the second prototype version and repeat in FY2013
  - When the test is successfully completed, we have a 5-kW absorber
- Jan 2013 – complete specifications for the full – size absorber
- Sep 2013 – detailed conceptual design of the absorber
  - If the test goes smoothly, it can be close to a technical design

Plans for FY13 – quadrupoles

- Magnetic design – Vl. Kashikhin, mechanical design – W. Robotham
- Prototype technical design is ready – Jan 2013
  - An assembly including a triplet (two smaller magnets and one larger) and a pair of dipole correctors
- Manufacturing is done – July 2013
  - The scope depends on the final cost estimation and money available
    - Preferably, a full triplet with the correctors
- Assembly and measurements at Fermilab finished – Aug 2013
- Final production drawings are ready – Sep 2013
- There is a discussion with BARC (Mumbai, India) about producing all quads

Plans for FY13 – buncher cavity

- The goal is to have a full set of production drawings in FY13
  - Pre-production review in 2012
    - A separate report at PX meeting sometime soon
  - The drawings may be ready around Feb 2013
  - If additional ~50k$ is available, a prototype cavity can be manufactured and tested in FY13

Plans for FY13 – diagnostics

- BPM development
  - BPM pickup prototype
    - Jan 2012 – drawings are ready
    - May 2013 – the sensor is ready to be assembled with the quads
  - Electronics
    - Based on development for NML
    - Specific development may start toward the end of FY13
- Emittance monitor
  - Specifications- Nov 2012
  - Conceptual design – Jan 2013
    - … or decision to copy/order
  - If possible, have the production drawings ready by Jul 2013
- Specifications for all diagnostics
  - Toroid, DCCT, wire scanner, fast Faraday cup, extinction monitor, laser wire

Beyond FY13: scenarios for PXIE MEBT

- Good (technically – driven) scenario: enough money
  - Order final versions of most of MEBT elements in FY2014
    - Quadrupoles, absorber, kickers and drivers, bunching cavities and their drivers, vacuum system, scrapers, part of diagnostics
  - Speed up development of a complete set of diagnostics
  - Assemble a nearly full – scope MEBT by the end of 2014
- Likely scenario : money is limited to ~ present level
  - What to choose to keep moving at a reasonable pace?
  - Transverse focusing reflects the logic of the MEBT design. My suggestion is to start with the full length and all quads to allow a reasonable study program and further incremental development
  - => “Phase I”
  - Be ready with drawings and specs if the budget situation changes

Possible "Phase I" of PXIE MEBT

- Assumptions:
  - LEBT is in a nearly final configuration
    - With the chopper commissioned
  - RFQ arrives in time, RFQ driver is in place, and RFQ assembly and commissioning goes similar to SNS'
- Goal:
  - assemble a skeleton of a full-size MEBT by the time when RFQ is commissioned (beginning of 2015)
- Requires:
  - All quads/correctors and BPMs with their final stands and cabling
  - Minimum of other diagnostics
  - Some of power supplies may be borrowed/(used for several quads)/(used underrated – for correctors)
  - Prototypes installed instead of final devices
  - Vacuum system in a minimal configuration

How to get to the Phase I

- Highest priorities:
  - Manufacture all quads and correctors in FY14
    - The most expensive item
  - Manufacture all BPMs and corresponding electronics in FY14
- Buy/manufacture/borrow
  - Toroid, emittance scanner, minimum vacuum system, driver for the bunching cavity, power supplies for quads and correctors
- Install prototypes into the corresponding sections
  - Buncher cavity
  - 5 kW absorber
  - Both kickers
  - Scrapers
- Be ready with specs for the final quads/correctors power supplies, cavity drivers, and kicker drivers
- Be ready with final drawings for the cavity, absorber, kickers, scrapers

What can be done in "Phase I" configuration

Slow valve, toroid	Scrapers RF	Emittance monitor, laser wire, scraper, wire scanner	Kicker	RF, wire scanner, Fast Faraday Cup	Kicker	Absorber	Different. pumping, scrapers, wire scanner	Scrapers, RF, slow valve, extinction monitor	Fast valve, DCCT, toroid, laser wire, wire scanner	Slow valve

- Almost full characterization of the beam from RFQ
  - Current, energy, transverse emittance and tails
    - Toroid, emittance monitor, scrapers
  - Estimation of the longitudinal size
    - Phasing the kicker and scanning over the absorber edge
- Optics measurement and corrections (wrong wiring, alignment etc.)
  - BPMs, dipole correctors, quad PSs
- Absorber prototype performance with beam
  - H- - specific issues: outgassing, blistering, estimation for sputtering
- First stage of protection system

What can be done in "Phase I" configuration (cont.)

Slow valve, toroid	Scrapers RF	Emittance monitor, laser wire, scraper, wire scanner	Kicker	RF, wire scanner, Fast Faraday Cup	Kicker	Absorber	Different. pumping, scrapers, wire scanner	Scrapers, RF, slow valve, extinction monitor	Fast valve, DCCT, toroid, laser wire, wire scanner	Slow valve

- Kicker prototypes' performance with beam
  - Survival
    - In several stories about kickers, their fate was determined more by survival than by RF quality
    - Important characteristic for the technology choice
  - Procedures: kicker efficiency, effective emittance growth, phase velocity
    - Scanning of the shifted beam over the absorber edge
    - Emittance scanner moved to the end of the line
- Prepare and commission the control system and most of infrastructure
  - Basic ACNET pages with later development of more sophisticated tools
  - Supports, cables, penetrations, control room etc.
- Incremental upgrade toward the final design
  - Section by section

What is unlikely to be tested in Phase I

- Kicker with final RF characteristics
  - Making a good kicker with the first attempt is not very probable
  - Buying full-power drivers for 50-Ohm version might be difficult
- 21 kW absorber
- Low- loss beam transport
  - Pumping is likely will be inadequate
- Bunch-by-bunch selection and extinction measurements
  - Lack of diagnostics and final-parameters kickers
- Differential pumping
- Mimicking an operation
  - Lack of diagnostics and control tools
  - Too far from final parameters

Summary

- Status
  - Overall concept, optics - stable
  - Prototypes for kickers, absorber, bunchers are under development
  - Quadrupoles, vacuum, BMPs – conceptual design
  - Other diagnostics – ideas
- FY13
  - Prototypes for kickers, absorber, quadrupoles, BPMs
  - Conceptual design for the absorber (update), vacuum system, scrapers, emittance monitor
  - Specifications for all diagnostics, power supplies, infrastructure
- Phase I proposal
  - Skeleton of a full-length MEBT with all quads and BPMs installed
  - Start with prototypes
  - Allows making a good progress
  - Incremental updates when money is available